Suppression of cladding mode coupling in Bragg grating using GeO_2-B_2O_3 codoped photosensitive cladding optical fibre

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A new type of photosensitive optical fibre codoped with GeO_2-B_2O_3 in both the core and cladding has been fabricated for applications in Bragg gratings. Coupling of the fundamental core mode into the cladding modes was suppressed with a narrow 3dB bandwidth in the Bragg grating. An increase in photosensitivity was also achieved by using high reflectivity Bragg gratings imprinted without the need for any hydrogen treatment.

Photoinduced fibre Bragg gratings (FBGs) have received consistent attention in areas of application such as narrowband reflection filters, add-drop filters, dispersion compensators and sensors [1]. In a high reflectivity grating, however, a wide loss band due to cladding mode coupling restricts the use of FBGs particularly in dense wavelength division multiplexing (WDM) systems. Coupling from the forward-propagating fundamental core mode into discrete backward-propagating cladding modes has been attributed to non-uniform effective index modulation over the fibre cross-section and the inherent asymmetry of the blazed FBGs resulting in significant losses below the Bragg wavelength [2].

Various optical fibre designs have been proposed to reduce the cladding mode coupling loss [3 – 5]. In particular, in terms of uniform index modulation, it has been proposed that the photosensitive area be extended into the inner cladding region by codoping with GeO_2 and F [3]. This approach is of interest because two profiles, the refractive index profile and photosensitivity profile, can be designed separately such that the guiding properties of the fundamental core modes are determined by the refractive index profile, while the overlap integral between the core mode and cladding modes is determined by the photosensitivity profile.

Among various silica based glass hosts, silica codoped with B_2O_3 with GeO_2 has been reported to have enhanced photosensitivity by an order of magnitude [6]. However only a few applications of this glass composition in FGBs have been reported.

In the work described in this Letter, uniform index modulation over the inner cladding region has been achieved by utilising highly photosensitive GeO_2-B_2O_3 codoped silica glass, leading to a new type of photosensitive optical fibre for FBGs in WDM device applications. The fibre was designed to suppress cladding mode coupling as well as to enhance the photosensitivity by adjustment of the GeO_2 and B_2O_3 concentration both in the core and cladding regions, which is reported for the first time, to the best of our knowledge.

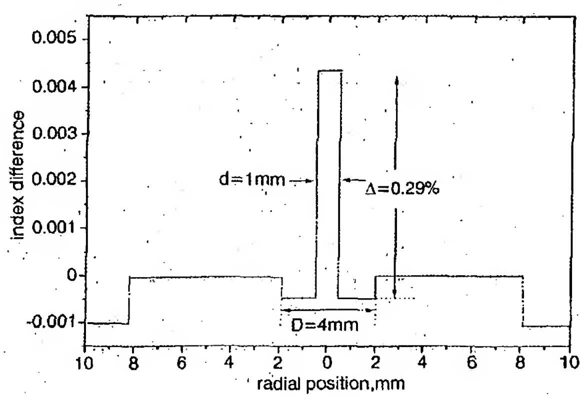

Fig. 1 *Preform index profile*

d: core diameter
D: inner cladding diameter

The preform was made by a modified chemical vapour deposition process using BCl_3 and $GeCl_4$ as precursors of their oxides. The structure of the preform is shown in Fig. 1. The core was doped with 7 mol% GeO_2 and 20.15 mol% B_2O_3. The inner cladding was doped with 1.25 mol % GeO_2 and 5.8 mol% B_2O_3. Note that the inner cladding diameter to core diameter ratio was kept to 4 to increase the photosensitive area. The total index difference Δ was set to 0.294%, similar to that of conventional singlemode fibre, to reduce the splicing loss. The optical fibre was drawn from the preform with LP_{11} mode cutoff at 900nm.

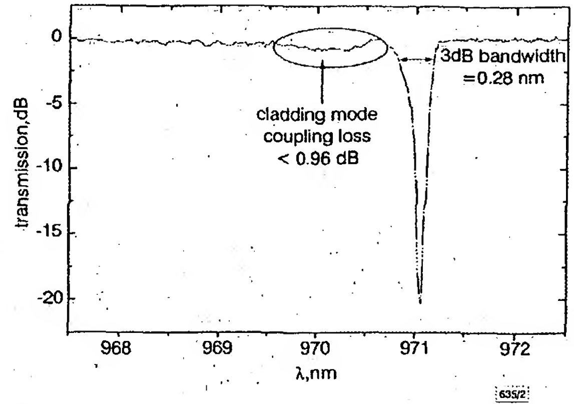

Fig. 2 *Transmission spectrum of Bragg grating imprinted on specially designed fibre*

Note: centre of Bragg grating, λ_B = 971.05nm and maximum transmission rejection = –21dB, corresponding to maximum reflectivity of 99.23%

Without any hydrogen treatment, a Bragg grating was formed in the fibre by irradiating it with 248nm KrF laser at 165mJ^{-2} per pulse, at a pulse repetition rate of 20Hz over a phase mask. The transmission spectrum of the imprinted Bragg grating is shown in Fig. 2. To utilise the Bragg reflection filter in dense WDM systems, both narrow bandwidth and high reflectivity are required as well as the suppression of cladding mode coupling losses. A peak reflectivity of 99.23% and 3dB bandwidth of 0.28nm were achieved. The maximum cladding mode coupling loss was measured to be < 0.96dB. In conventional hydrogen treated FBG filters, post-annealing is necessary to stabilise the spectral response. The intrinsic high photosensitivity of the fibre in this study obviated the need for not only the hydrogen loading process before imprinting of the FBGs but also the post-annealing process.

Table 1: Comparison of Bragg grating imprinted on specially designed fibre with previous results

	H_2 loading	Peak reflectivity	3dB bandwidth	Maximum cladding mode coupling loss
		%	nm	dB
Fibre in this study	No	99.23	0.28	–0.96
GeO_2–F clad fibre [3]	Yes	99.68	0.6	–0.5
High NA fibre [4]	Yes	99.96	3	–2.5
Depressed inner clad fibre [5]	Yes	100	1.2	–0.46

In Table 1, we compare the results for our fibre grating with previous results such as for GeO_2-F inner clad fibre [3], high NA fibre [4], and a depressed inner clad fibre [5]. We confirmed that even though it is not yet fully optimised, our photosensitive fibre showed comparable suppression of cladding mode coupling loss, along with high reflectivity and narrow bandwidth without hydrogen treatment. The spectral loss near 1.5µm in this fibre was, however, found to be very high due to a B-O vibration absorption band and further optimisation of the glass composition, especially in the core, is being studied for FBGs in the 1.5µm communication window.

In summary, through the use of a newly designed optical fibre with a GeO_2-B_2O_3 codoped photosensitivity profile, the suppression of cladding mode coupling losses to < 0.96dB, a high reflectivity of 99.23% and a 3dB bandwidth of 0.28nm have been achieved without the need for any hydrogen treatment.

Acknowledgments: This work was partly supported by UFON, and the ERC program in K-JIST.

© IEE 1999 2 December 1998
Electronics Letters Online No: 19990168
DOI: 10.1049/el:19990168

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